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FLUID AMPLIFIER SYMBOLS, NOMENCLATURE, AND SPECIFICATION

Prepared under Contract No. NAS 8-5408 *by*
GENERAL ELECTRIC COMPANY
Schenectady, N. Y.
for

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Table of Contents

FOREWORD

This manual was prepared for the Astrionics Laboratory of the George C. Marshall Space Flight Center, National Aeronautics and Space Administration, to provide standardization in the no-moving-part fluid amplifier field for NASA use. The Manual is relatively concise and general to encourage its use as this new field develops; detailed standards in such a new field are not considered appropriate at this early stage of development. We are convinced, however, that the Manual will prove to be very useful in the exchange and interpretation of technical information between laboratories and at symposia.

The information presented in the Manual represents an "average" usage in Government and industrial laboratories active in the technology. Contributions from such groups were obtained by means of a detailed questionnaire.

We wish to acknowledge the cooperation of the contributing laboratories (see Appendix) which made this Manual more meaningful. We also wish to acknowledge the contributions of Mr. R. E. Currie of the Astrionics Laboratory who originally suggested the preparation of the Manual. The work was carried out under his direction on contract NAS 8-5408.

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Advanced Technology Laboratories
General Electric Company
Schenectady, New York

1.0 TERMINOLOGY

Definition and terms are presented in this section for the general field of fluid amplifiers and the major features of commonly used devices.

1.1 General

FLUID AMPLIFIERS	- The general field of fluid no-moving-parts control and logic devices.
ELEMENTS	- Fluid amplifiers and logic devices which are interconnected to form working circuits. Also the general class of devices used in conjunction with fluid amplifiers in circuits; for example, fluid restrictors and capacitors.
CIRCUITS	- Arrays of interconnected elements which perform specialized functions or standard functions such as integrators and counters.
PROPORTIONAL	- The general class of elements or circuits having analog characteristics, i. e., output is proportional to input.
DIGITAL	- The general class of elements or circuits which have digital or "on-off" characteristics.
PRESSURE AMPLIFIER	- An element designed specifically for amplifying pressure signals.
FLOW AMPLIFIER	- An element designed specifically for amplifying flow signals.

(1.0 Terminology - Cont.)

POWER AMPLIFIER	- An element optimized to provide maximum power gain.
VALVE	- A fluid amplifier which has the end use of diverting or modulating fluid flow,(i.e., bypass or process control valves).
ACTIVE vs. PASSIVE	- A fluid amplifier which is attached to the power supply is designated active; one which operates on input signal power is identified as a passive element.

1.2 Proportional Amplifiers

BEAM-DEFLECTOR	- Proportional amplifier which uses control pressure and/or flow to deflect a fluid jet or "beam" for the functional operating principle.
VENTED vs. CLOSED PROPORTIONAL AMPLIFIERS	- An open amplifier utilizes vents to establish the ambient pressure in the interaction region; a closed amplifier has no communication with the local ambient. Terminology for the geometry of vented and closed beam-deflector amplifiers is listed on Figure 1 and 2 on the following page.

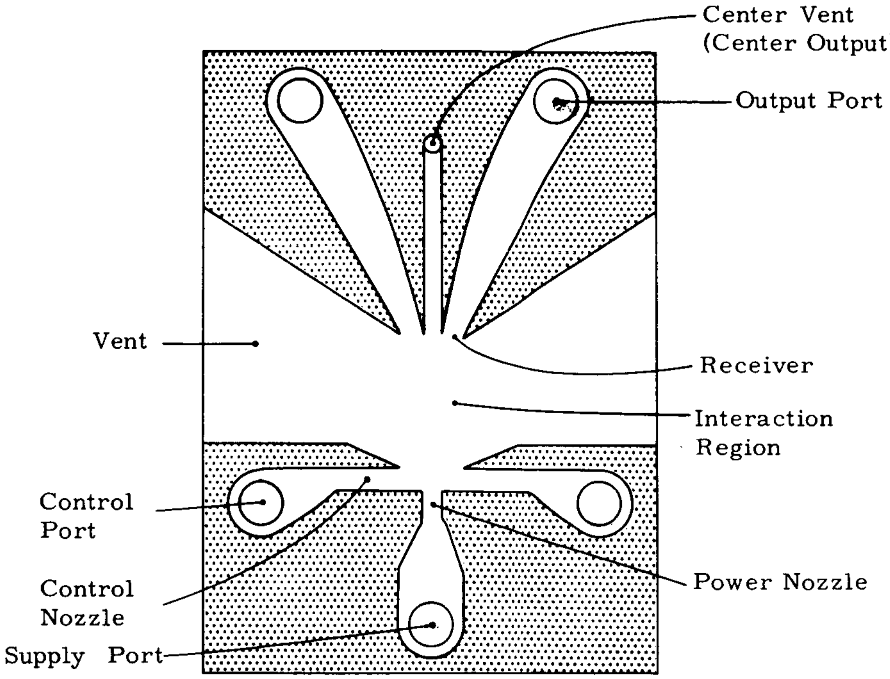


Figure 1. Vented Proportional Amplifier.

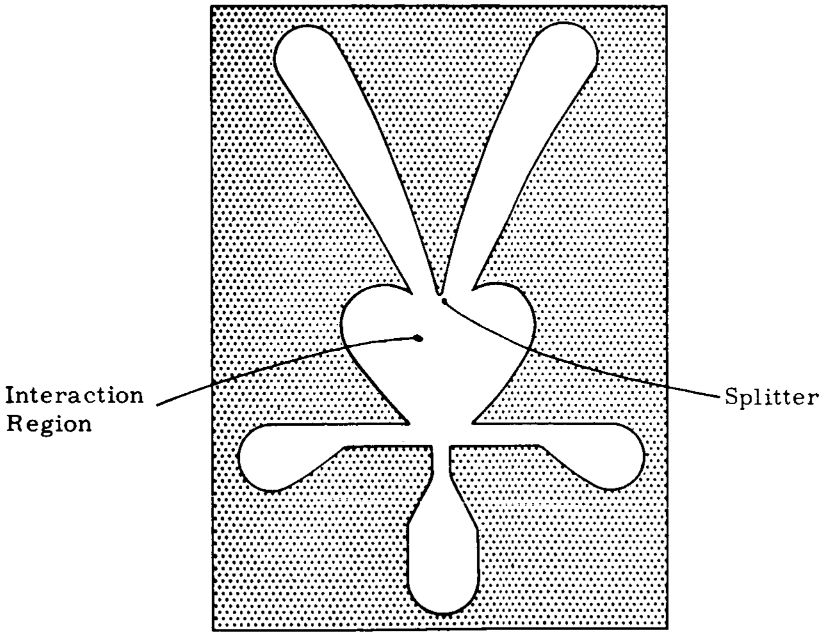


Figure 2. Closed Proportional Amplifier.

VORTEX - An amplifier which utilizes the pressure drop across a vortex for the modulating principle.

- Terminology for the geometry of a vortex amplifier is listed on the sketch below.

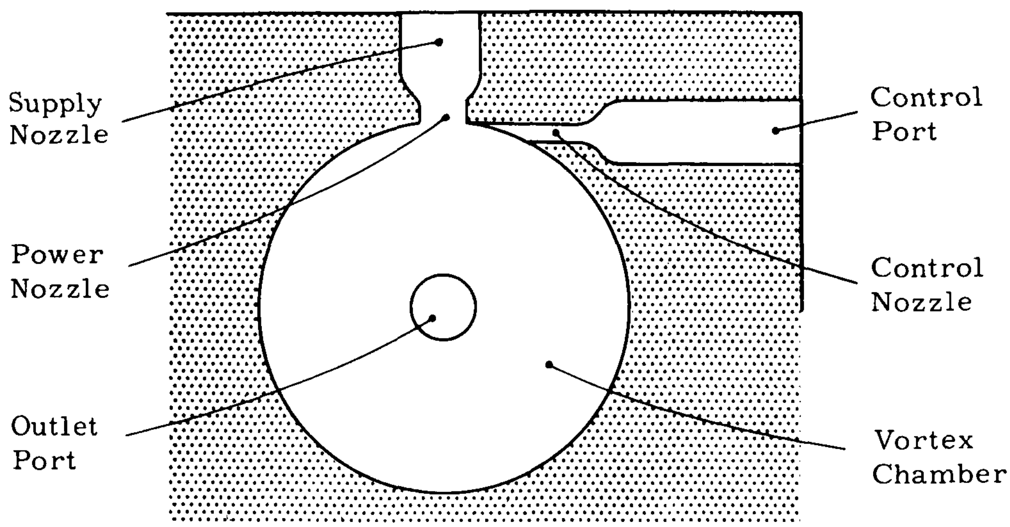


Figure 3. Vortex Amplifier

1.3 Digital Fluid Amplifiers

FLIP-FLOP - A digital element which has a hysteresis loop of sufficient width so that it has "memory". Its state is changed with an input pulse; a continual input signal is not necessary for it to exhibit bistability.

DIGITAL AMPLIFIER - A digital element which provides amplification and has negligible hysteresis (i.e., no memory). Therefore a continual input signal is required to maintain a given state of bistability.

LOGIC ELEMENTS - The general category of digital fluid amplifiers which provide logic functions such as AND, OR, and NOR. They can gate or inhibit signal transmission with the application, removal, or other combinations of input signals.

WALL ATTACHMENT AMPLIFIERS - Digital devices which use jet attachment to a wall (Coanda effect) for the basic operating principle.

- Principle features of a wall attachment amplifier are identified in Figure 4 below.

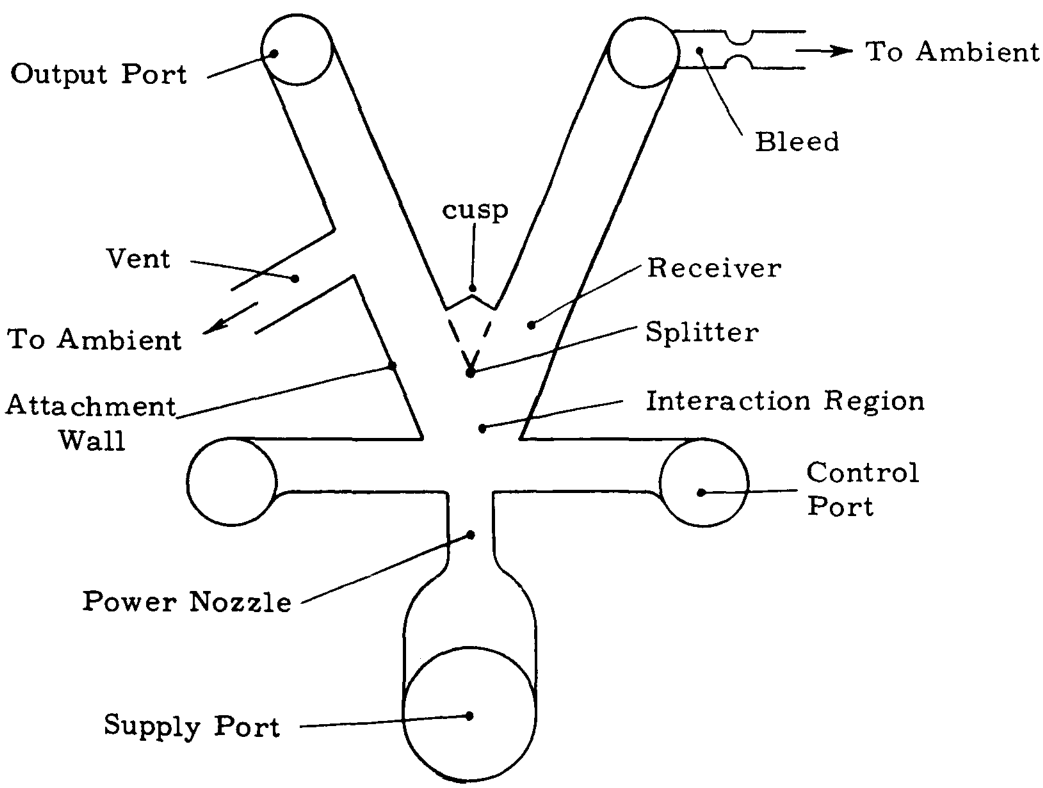


Figure 4. Digital Fluid Amplifier.

TURBULENCE AMPLIFIER - Digital element which utilizes for the basic operating principle the laminar-to-turbulent transition of a jet produced by input signal flow.

1. 4 Circuit Elements

FLUID IMPEDANCE - Passive fluid element which requires a pressure drop to establish a flow through it. Transfer function may have real, imaginary, or both components.

FLUID RESISTOR - Fluid element which produces a pressure drop as a function of the flow through it and has a transfer function of essentially real components (i. e., negligible phase shift) over the frequency range of interest. Pressure-flow characteristics may vary from square-law relationship for orifices with incompressible fluid to linear relationship characterized by capillary flow.

FLUID CAPACITOR - Fluid impedance element in which pressure drop lags flow into it by essentially 90°.

FLUID INDUCTOR - Fluid impedance element in which pressure drop leads flow by essentially 90°.

FLUID DIODE - Element which has high resistance to flow in one direction compared to that in the opposite direction.

SENSOR	- A fluid element which, in general, senses quantities or media other than those related to fluids and converts them into fluid quantities (e. g. , a fluid oscillator used to sense temperature or a vortex gyro to sense angular rate).
TRANSDUCER	- A device which converts signals in other than fluid media into fluid signals (e. g. , electrical to pneumatic) or the converse.

2.0 NOMENCLATURE

Nomenclature for the more commonly used quantities is listed below. Only those quantities often used on the interchange of information are included; a complete listing, including terms in other fields such as boundary layer theory and jets, is not considered appropriate at this time.

Two sets of units are listed. Those without parenthesis are those now in most common usage. Those in parenthesis are the International System of Units (SI units) which NASA now is evaluating and soon may adopt.

2.1 Basic Quantities

The quantities listed below are general; specific quantities should be identified by subscripts (e.g., P_{O2} would be pressure at port O2). The most commonly used units in the fluid amplifier field appear to be the English system with the "pound" as a unit of force. In addition, flow units generally are on the basis of pounds-per-unit-time. Hence, nomenclature for specific weight is included to delineate it from mass. Quantities such as fluid resistance, capacitance and inductance then use units of weight flow instead of mass flow to be consistent with this more common usage.

Quantity	Nomenclature	Units	
		(Std)	(SI)
Length	--	inch; in	(meter, m)
Force	F	pound, lb	(newton; N)
Mass	m	lb-sec^2/in	(kilogram; kg)
time	t	seconds; sec	(seconds; s)
angle	--	degrees; ^{o}	(radians; rad)
frequency	f	cycles/sec; cps	(hertz; H_z)

Quantity	Nomenclature	Units (Std)	Units (SI)
area	A	in^2	(m^2)
acceleration	a	in/sec^2	(m/s^2)
gravitational constant	g	in/sec^2	(m/s^2)
temperature, static	T	degrees Rankin; ^oR	(degrees Kelvin; ^oK)
temperature, total	T_T	^oR	^oK
velocity, angular	ω	rad/sec	(rad/s)
acceleration, angular	α	rad/sec^2	(rad/s^2)
gas constant	R	$in/^oR$	$(N\text{-}m/kg\text{-}^oK)$
volume	V	in^3	(m^3)
weight density	γ	lb/in^3	(N/m^3)
mass density	ρ	$lb\text{-}sec^2/in^4$	(kg/m^3)
weight flow rate	w	lb/sec	(N/s)
mass flow rate	$\dot{m}$	lb-sec/in	(kg/s)
momentum	$\overline{m}$	lb-sec	(kg-m/s)
volume flow rate	Q	in^3/sec	(m^3/s)
velocity, general	u	in/sec	(m/s)
velocity, mean	$\bar{u}$	in/sec	(m/s)
velocity, acoustic	u_c	in/sec	(m/s)
pressure, general	P	lb/in^2 or psi	(N/m^2)
pressure, absolute	P	psia	(N/m^2)
pressure, gage or drop	P	psig	(N/m^2)

Quantity	Nomenclature	Units (Std)		Units (SI)
specific heat ratio	k		dimensionless	
absolute viscosity	μ	lb-sec/in^2		(N-s/m^2)
kinematic viscosity	ν	in^2/sec		(m^2/s)
liquid bulk modulus	β	lb/in^2		(N/m^2)
efficiency	η		dimensionless	
fluid impedance	Z		general	
fluid resistance	R_x	sec/in^2		(N-s/m^2-kg)
(x = subscript should be used to delineate from gas constant "R")				
fluid capacitance	C	in^2		(kg-m^2/N)
fluid inductance	L	sec^2/in^2		(N-s^2/kg-m^2)
Mach number	M		dimensionless	
Laplace operator	s	1/sec		(1/s)
Reynolds number	N_R		dimensionless	
nozzle aspect ratio	σ		dimensionless	
Strouhal number	N_S		dimensionless	
pressure gain, average	G_p		dimensionless	
pressure gain, incremental	G_{Pi}		dimensionless	
flow gain, average	G_F		dimensionless	
flow gain, incremental	G_{Fi}		dimensionless	
power gain, average	G_{PF}		dimensionless	
power gain, incremental	G_{PFi}		dimensionless	
signal - noise ratio	S/N		dimensionless	

Linear Dimensions

Linear dimensions should be identified by lower case arabic letters (note a, f, g, k, m, s, t, u, and w are used above and are not available for dimension nomenclature). Also see dimensional nomenclature usage defined in Figures 5 and 6.)

General Subscripts

control	C
output	O
supply	S
control, quiescent	CO

2.2 Fluid Amplifier Geometry

Nomenclature for the beam deflector proportional amplifier and the wall attachment digital amplifier are identified on the sketches below. These two types of amplifiers are included in the manual because of their widespread usage in many of the laboratories involved in fluid amplifier work. Only the major nomenclature is shown; detail nomenclature is not practical at this time. The sketches are for illustrative purposes and are not intended to suggest design practices.

Proportional Amplifier (see Figure 1 for description)

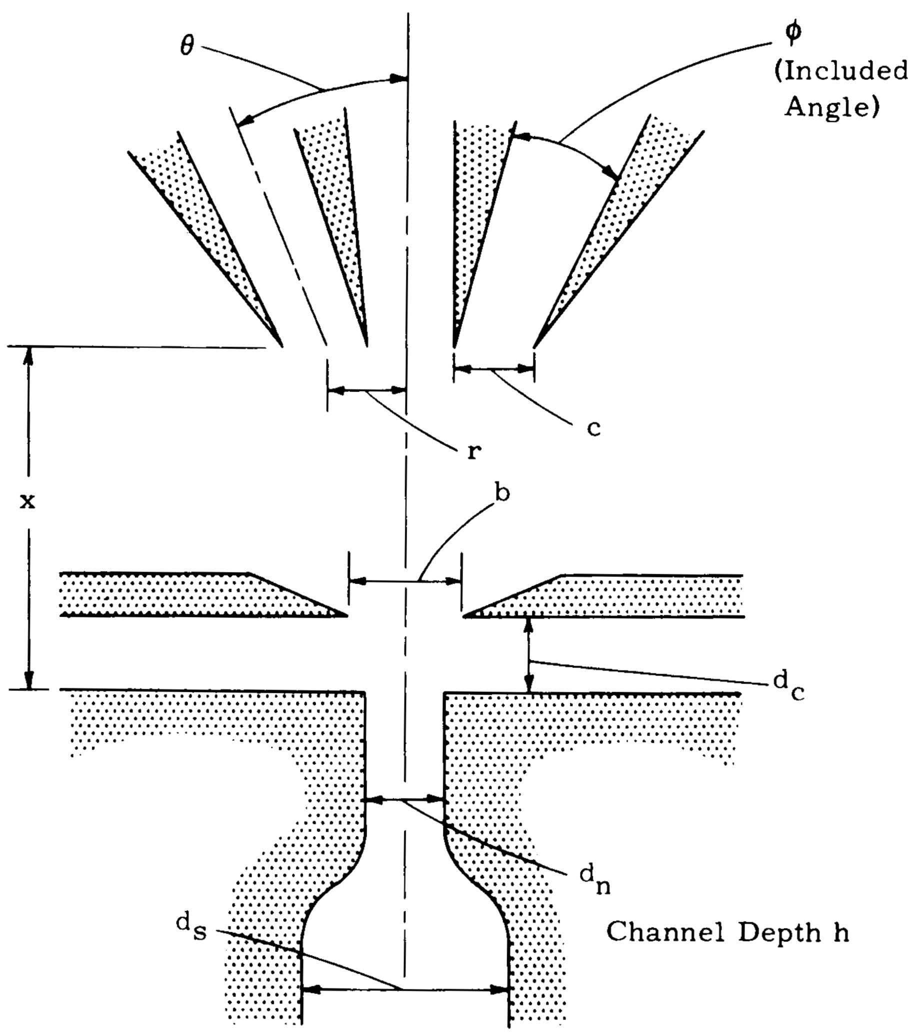


Figure 5

Digital Amplifier (see Figure 4 for description)

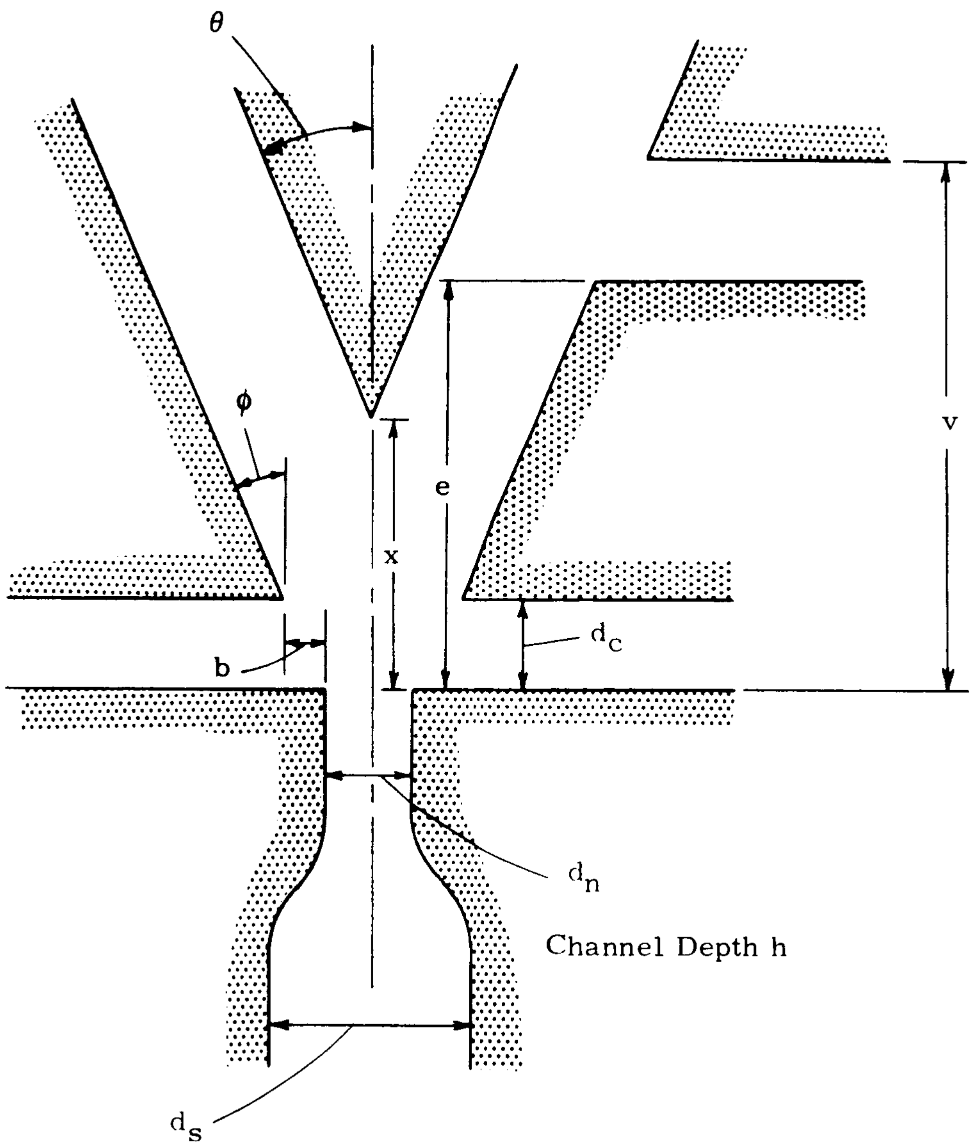


Figure 6

3.0 DEFINITION OF PARAMETERS

The definition of parameters below are made, wherever possible, in terms of the nomenclature listed in Section 2.0. The more commonly used units are listed (no parentheses) along with the International System of units (in parentheses) which are under consideration by NASA.

3.1 General

REYNOLDS NUMBER, NOZZLE - N_R, ratio of inertial to viscous forces in a nozzle.

$N_R = \frac{u\, d_h}{\nu}$ (dimensionless)

where d_h (hydraulic diameter) $= 4A/E$, A = cross section area of channel and E = wetted perimeter.

STROUHAL NUMBER - N_S, ratio of a time delay (such as switching time) to fluid transport time over a characteristic distance; $N_S = \frac{t}{y/u}$ (dimensionless). Where y is the characteristic dimension and u is the average fluid velocity over the distance y.

FLUID RESISTANCE - R_x (x - subscript to identify resistance); for average value, resistance is the ratio of pressure drop (ΔP) to weight flow rate:

$$R_x = \frac{\Delta P}{w} \quad \frac{sec}{in^2} \quad \left(\frac{Ns}{m^2\, kg}\right)$$

For incremental fluid resistance:

$$R_x = \frac{dP}{dw} \quad \frac{sec}{in^2} \quad \left(\frac{Ns}{m^2\, kg}\right)$$

(3.0 Definition of Parameters, Cont.)

FLUID CAPACITANCE - C; ratio of integrated weight flow to change in pressure.

for gases $C = \frac{V}{k\,R\,T}$ in^2(m^2 -kg/N)

for liquids $C = \frac{\gamma V}{\beta}$ in^2 (m^2 -kg/N).

In general $\Delta P = \frac{1}{Cs} \Delta w$

where ΔP represents a small change in pressure and Δw represents a small change in net weight flow rate.

(s = Laplace operator)

FLUID INDUCTANCE - L; ratio of pressure change (ΔP) to rate of change of weight flow ($s\Delta w$)

$$L = \frac{y}{g\,A} \quad \frac{\sec^2}{in^2} \left(\frac{s^2\,N}{m^2\,kg} \right)$$

where y = channel length and

A = channel cross sectional area.

In general $\Delta P = Ls\Delta w$

where ΔP represents a small change in pressure drop along a channel and Δw represents a small change in weight flow rate.

ASPECT RATIO, NOZZLE - σ; ratio of nozzle depth (h) to nozzle width (d_n).

3.2 Proportional Fluid Amplifiers

PRESSURE GAIN - G_P, average gain; defined as the slope of a straight line drawn through a measured input-pressure/output-pressure curve so that deviations from the measured curve, up to the maximum output level, are minimized. Deviations should be based on net area as shown in Figure 7. If other than maximum output level is used for average gain definition, the range used should be noted. Gage pressure values should be used. Measured curve to be for either zero output flow or a value which provides maximum pressure gain.

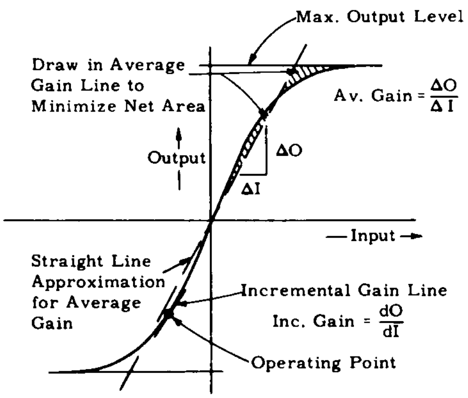


Figure 7

G_{Pi}, incremental gain; defined as the slope of the measured input-pressure/output-pressure curve at the operating point of interest (See Figure 7).

FLOW GAIN

G_F, average gain; defined as the slope of a straight line drawn through an input-flow/output-flow curve so that deviations from the measured curve, up to the maximum output level are minimized.

Deviations should be based on net area as shown in Figure 7. If other than maximum output level is used for average gain definition, the range should be noted. Measured curve to be for either low output pressure recovery (resulting from instrumentation) or a value which provides maximum flow gain.

- G_{Fi}, incremental gain; defined as the slope of the measured input-flow/ output-flow curve at the operating point of interest.

POWER GAIN

- G_{PF}, average power gain; ratio of the change in output power to the change in input power; average value over operating range up to maximum output level unless range is stated. Power gain is defined as follows for incompressible and low pressure compressible fluids:

$$G_{PF} = \frac{P_{O2}\, w_{O2} - P_{O1}\, w_{O1}}{P_{C2}\, w_{C2} - P_{C1}\, w_{C1}}$$

For a differential amplifier, subscripts 1 and 2 refer to right and left control and output ports. For "single-ended" amplifiers subscript 2 denotes final value and subscript 1 denotes initial value or null condition. (Power gain is not the product of pressure gain and flow gain.)

- G_{PFi}, incremental power gain; defined as the slope at the operating point of an input-output power curve.

SATURATION - The maximum output value regardless of input magnitude. See Figure 8.

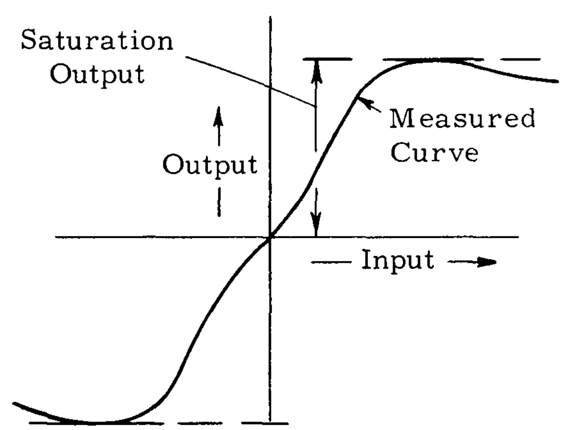


Figure 8

LINEARITY - Deviation of the measured curve from the straight-line average gain approximation; defined as the ratio of the peak-to-peak output deviation to peak-to-peak output range (range should be stated if other than maximum output level) expressed as a percentage. (See Figure 9)

Linearity (%) = $\frac{y}{z} \times 100$

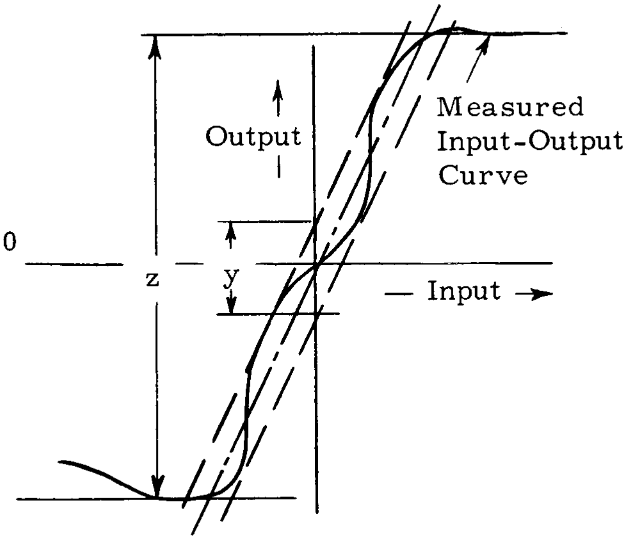


Figure 9

HYSTERESIS - Total width of hysteresis loop expressed as a percent of peak-to-peak saturation input signal. Measurement to be at frequencies below those where dynamic effects become significant. See Fig. 10.

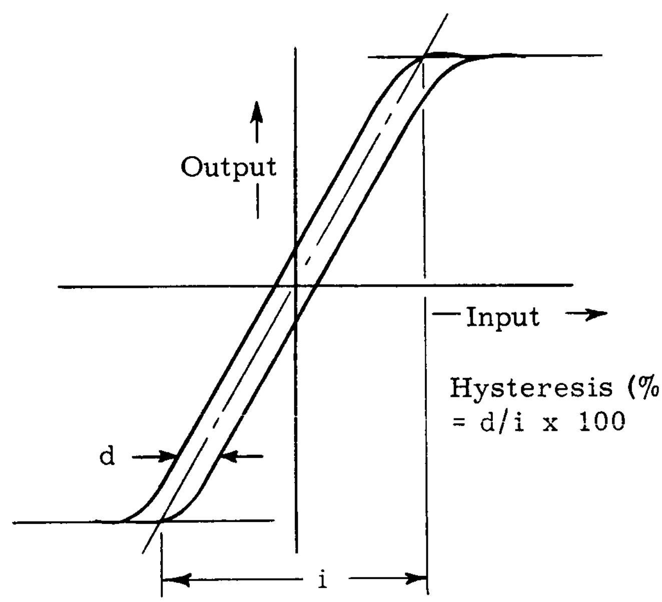


Figure 10

FREQUENCY RESPONSE	- Frequency at which phase lag is 45° (not necessarily the same as the "down-3db" point).
SIGNAL / NOISE RATIO	- S/N, ratio of maximum (saturation value) output signal amplitude to maximum noise amplitude (at output). Signal and noise data should be RMS values.
BIAS	- Magnitude of input signal to null or provide zero output signal for differential amplifiers; signal magnitude required to establish operating point for single ended amplifiers. Bias should be expressed as a percentage of the saturation input signal.
INPUT IMPEDANCE	- Z_C, the ratio of pressure change to flow change measured at an input port. Numerical value may depend on operating point since input pressure-flow curve may not be linear. (See Figure 11). For active elements the power source should be connected for measurements.

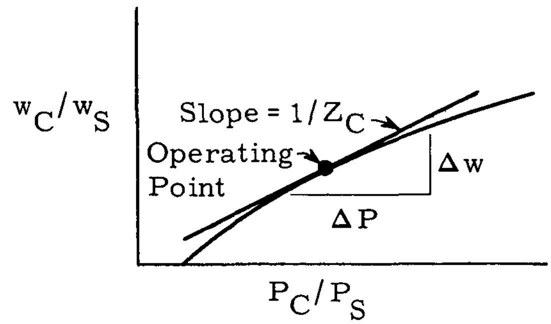


Figure 11

OUTPUT IMPEDANCE - Z_O, the ratio of pressure change to flow change measured at an output port. Numerical value may depend on operating point since output pressure-flow curve may not be linear. (See Figure 12).

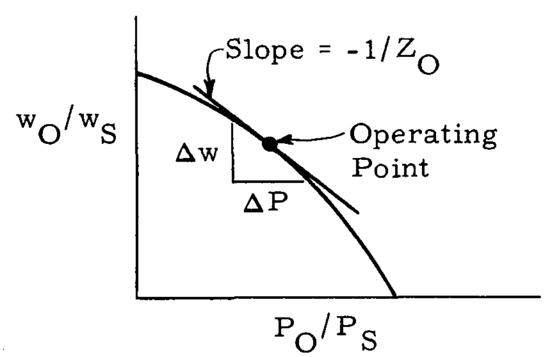


Figure 12

3.3 Digital Fluid Amplifiers

PRESSURE GAIN - G_P, ratio of measured output pressure change to input pressure change (from quiescent) required for switching to occur. All control ports except the one under consideration should be maintained at the quiescent pressure level. Output flow should be zero or value which results in maximum pressure gain. If gain value is for other than steady-state conditions, test frequency should be stated.

FLOW GAIN - G_F, ratio of output flow change to input flow change (from quiescent) required for switching to occur. Output pressure recovery should be low (resulting from instrumentation) or value which results in maximum flow gain. If gain value is for other than steady-state conditions, test frequency should be stated.

POWER GAIN - G_{PF}, ratio of the change in output power to change in input power (from quiescent) for switching to occur. For incompressible and low pressure compressible fluids, power gain is defined as

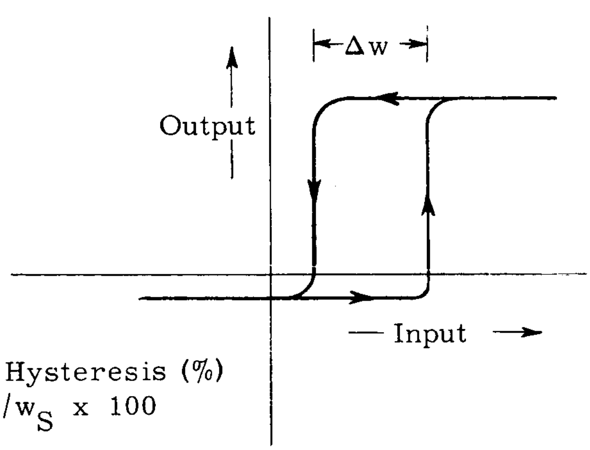
$$G_{PF} = \frac{P_{O2} w_{O2} - P_{O1} w_{O1}}{P_{C2} w_{C2} - P_{C1} w_{C1}}$$

where subscript 2 refers to final values and subscript 1 refers to initial or quiescent values. (Power gain is not the product of pressure gain and flow gain).

(3.0 Definition of Parameters - Digital Fluid Amplifiers, Cont.)

FANOUT - The number of elements which can be driven by a single element. All elements to be operated at the same supply pressure. Also elements to be of similar size (i.e., to have the same input impedance) and to have similar switchpoints. Fanout value stated to be for essentially steady-state operation unless the corresponding operating frequency is also listed.

ELEMENT HYSTERESIS - Width of the hysteresis loop as measured on an input-output curve and expressed as a percentage of the supply conditions, e.g., flow hysteresis is the hysteresis loop width (measured on an input-output flow curve) divided by the supply flow. (See Figure 13).



Flow Hysteresis (%) $= \Delta w/w_S \times 100$

Figure 13

INPUT IMPEDANCE - Z_C, the ratio of input pressure change to flow change measured at an input port; value may depend on operating point since input pressure flow curve may not be linear.

OUTPUT IMPEDANCE - Z_O, the ratio of output pressure change to flow change measured at an output port; value may depend on operating point since output pressure-flow curve may not be linear.

RESPONSE TIME - The time delay between the application of an input step signal and the resulting output step signal. The time measurements for the step signals are to be made at the 50% of final value point. (See Figure 14).

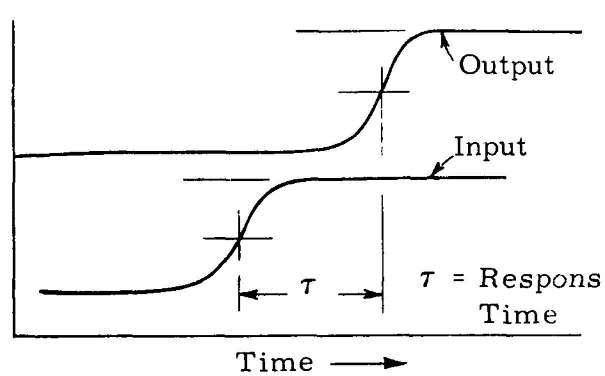


Figure 14

SIGNAL/NOISE RATIO - S/N; ratio of the amplitude of the output signal to the peak-to-peak maximum noise signal. Maximum noise signal to be measured when the port is active and inactive, greater value of the two used in calculating S/N ratio.

4.0 SCHEMATICS

Schematics for the more common proportional digital and general circuit elements are illustrated below. General delineations also are shown to aid in the selection of additional schematics.

4.1 General

Submerged jet path

proportional device

digital device.

Active vs. passive ports

port connected to fluid supply
to result in a power jet; active port

port connected for signal flow only; passive port

Memory vs. no hysteresis

arrow-head on control line indicates continual flow required to maintain state, no memory (no hysteresis)

no arrow-head on control line indicates element has memory (has useful hysteresis).

Logic Notation

$A \bullet B \equiv$ A "and" B

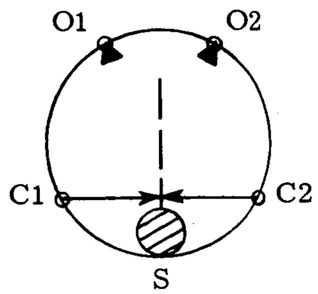
$A + B \equiv$ A "or" B

$\overline{A} \bullet \overline{B} \equiv$ "not" A and "not" B

(4. 0 Schematics, Cont.)

4. 2 Proportional Elements

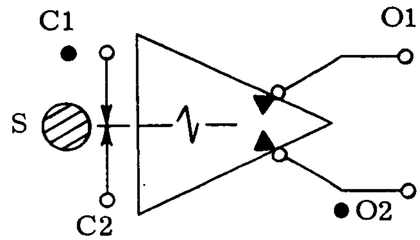
PROPORTIONAL
AMPLIFIER



S - supply
C1 - left control
C2 - right control
O1 - left output
O2 - right output

Operating Principle - beam deflector

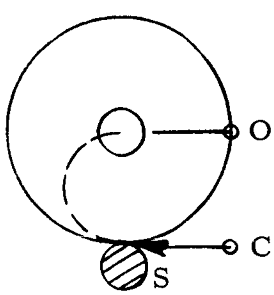
OPERATIONAL
AMPLIFIER



S - supply
C1, C2 - control ports
O1, O2 - output ports
(dot at input and output indicates polarity)

Operating Principle - beam deflector

VORTEX
AMPLIFIER



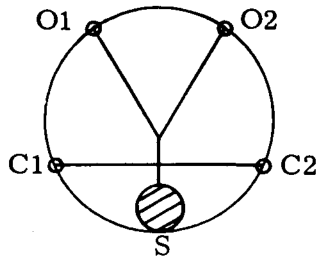
S - supply
C - control port
O - outlet

Operating Principle - vortex

4. 3 Digital Fluid Amplifiers

FLIP-FLOP

(has memory - relatively wide hysteresis loop)



S - supply

C1 - left control

C2 - right control

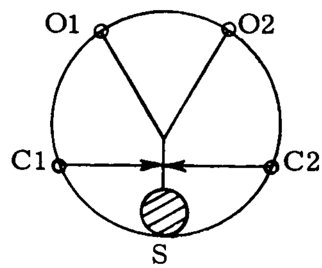
O1 - left output

O2 - right output

Operating Principle - wall attachment

DIGITAL AMPLIFIER

(no memory - essentially zero width hysteresis loop)



S - supply

C1 - left control

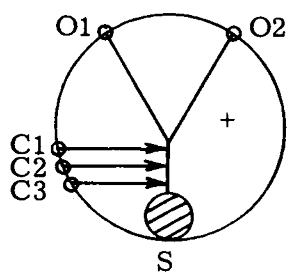
C2 - right control

O1 - left output

O2 - right output

Operating Principle - wall attachment

OR-NOR



S - supply

C1, C2, C3 - inputs

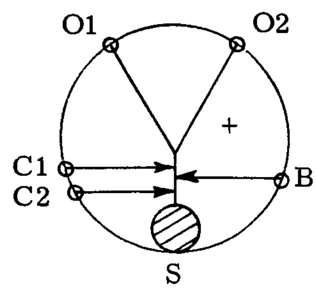
O1 - $\overline{C1} \cdot \overline{C2} \cdot \overline{C3}$ - output

O2 - C1 + C2 + C3 - output

Operating Principle - wall attachment, geometrical biasing

(4.0 Schematics - Digital Fluid Amplifiers, Cont.)

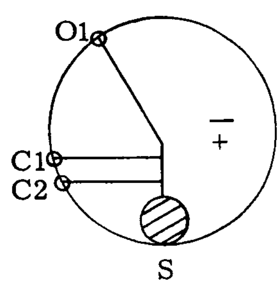
OR-NOR



S - supply
C1, C2 - input ports
O1 - left output
O2 - right output
B - bias port

Operating Principle - wall attachment, fluid biased

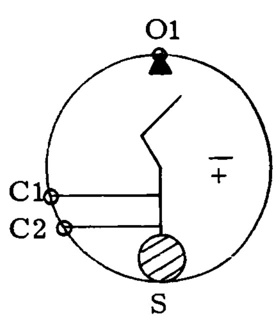
NOR



S - supply port
C1, C2 - input ports
O1 - output port

Operating Principle - wall attachment

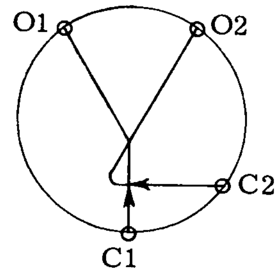
NOR



S - supply
C1, C2 - inputs
O1 - output

Operating Principle - turbulence

EXCLUSIVE OR



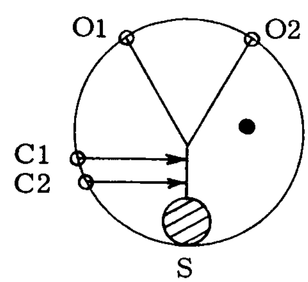
C1, C2 - inputs

O1 - $C1 \cdot C2$ output

O2 - $C1 + C2$ output

Operating Principle - wall attachment

AND



S - supply

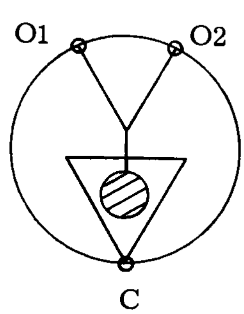
C1, C2 - inputs

O1 - $\overline{C1} + \overline{C2}$ output

O2 - $C1 \cdot C2$ output

Operating Principle - wall attachment

BINARY COUNTER STAGE



S - supply

C - input

O1 - left output

O2 - right output

Operating Principle - wall attachment

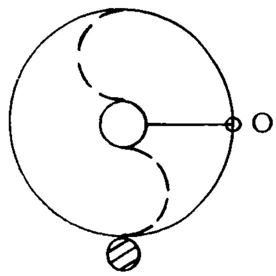
(4.0 Schematics - Cont.)

4.4 Sensors and Transducers

ANGULAR RATE
SENSOR (vortex type)

O - output

S - supply



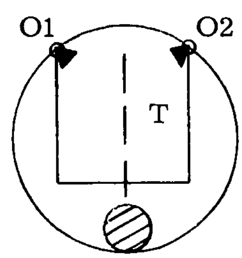
S

Operating Principle - vortex

TEMPERATURE
SENSOR (oscillator type)

O1, O2 - outputs

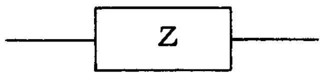
S - supply



S

Operating Principle - beam deflector

4. 5 General Circuit Elements

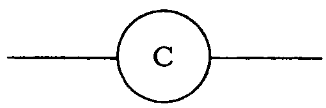


GENERAL IMPEDANCE

ORIFICE

CAPILLARY
(LAMINAR) RESTRICTION

INDUCTANCE



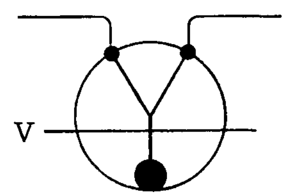
VOLUME OR ACCUMULATOR

DELAY LINE

CROSSING LINES

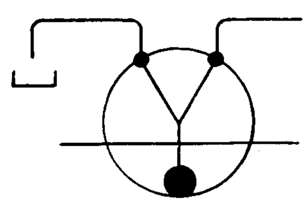
CONNECTING LINES

VENT CONNECTION



EXAMPLE OF VENT

RETURN TO RESERVOIR



EXAMPLE OF
RESERVOIR RETURN

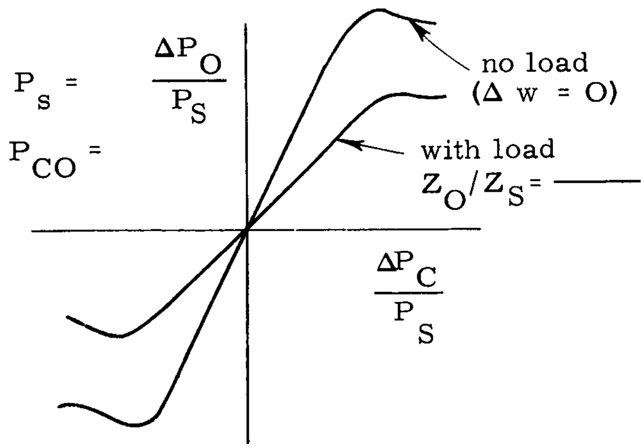
5.0 CHARACTERISTIC CURVES

Examples of suggested arrangements for displaying characteristic curves of fluid amplifiers are shown on the following pages. Although curves for only two elements (a flip-flop and a differential beam deflector amplifier) are shown, the arrangements can be readily modified to suit other fluid amplifier elements. Curves are shown for input-output, input and output characteristics.

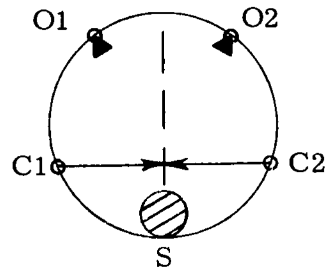
(5.0 Characteristic Curves, Cont.)

EXAMPLE A - Proportional

Device - Beam Deflector Amplifier



input - output curve



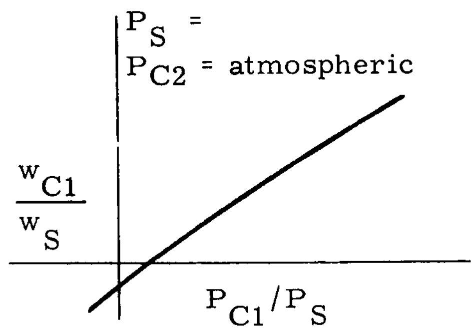
Schematic

$\Delta P = P_2 - P_1$

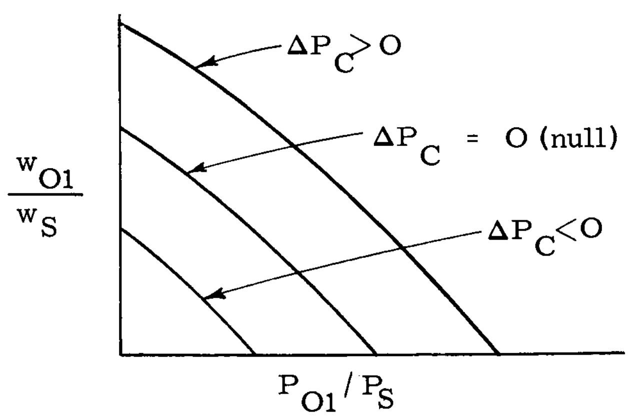
$\Delta w = w_2 - w_1$

in general

$\Delta P_O = - G \Delta P_C$



input characteristics

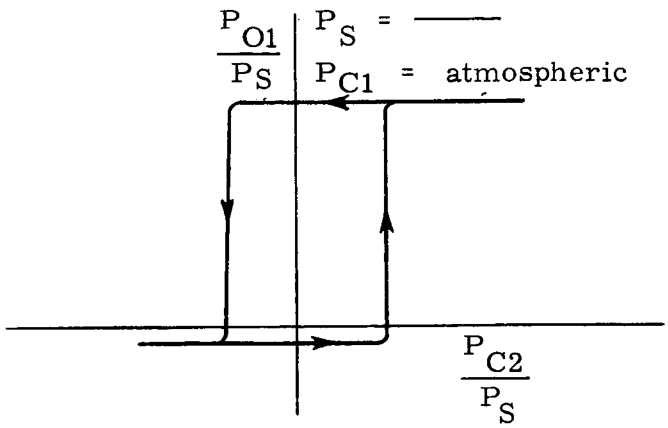


output characteristics

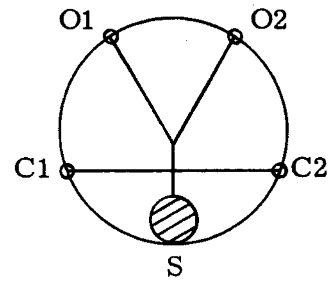
(5.0 Characteristic Curve, Cont.)

EXAMPLE B - Digital

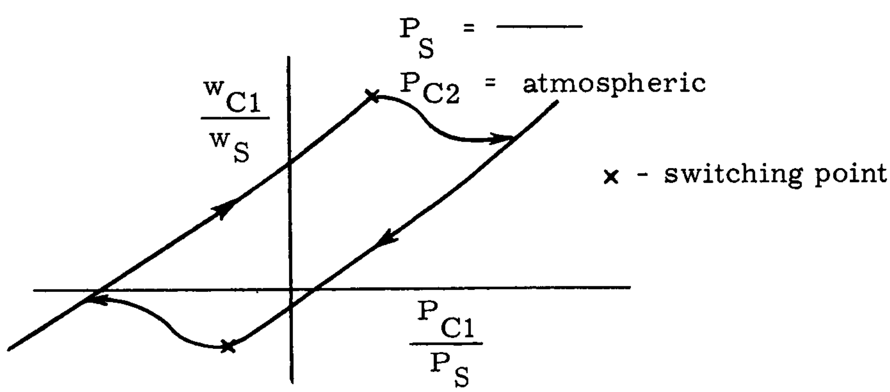
Device - Flip-Flop



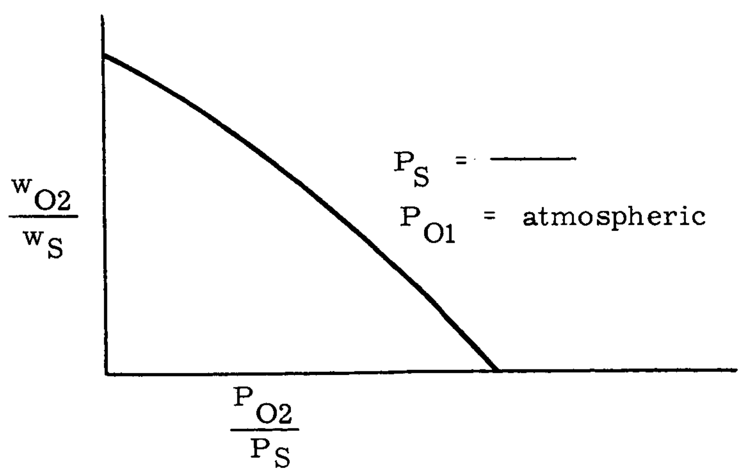
input - output curve



schematic



input characteristics



output characteristics

6.0 SPECIFICATION SHEET

A suggested format of a specification sheet for fluid amplifiers is illustrated on the following pages. The intent is to briefly list the general characteristics of a fluid amplifier to help the circuit designer in selecting elements and components.

(6.0 Specification Sheet, Cont.)

SAMPLE (numerical values listed are hypothetical) FRONT

FLUID AMPLIFIER SPECIFICATION SHEET

FUNCTION:	differential proportional amplifier
DESIGNATION:	PA44-2
OPERATING PRINCIPLE:	Beam Deflector
POWER NOZZLE SIZE:	d_n = 0.020 in; h = 0.040 in.
OUTLINE:	See reverse side
PERFORMANCE:	

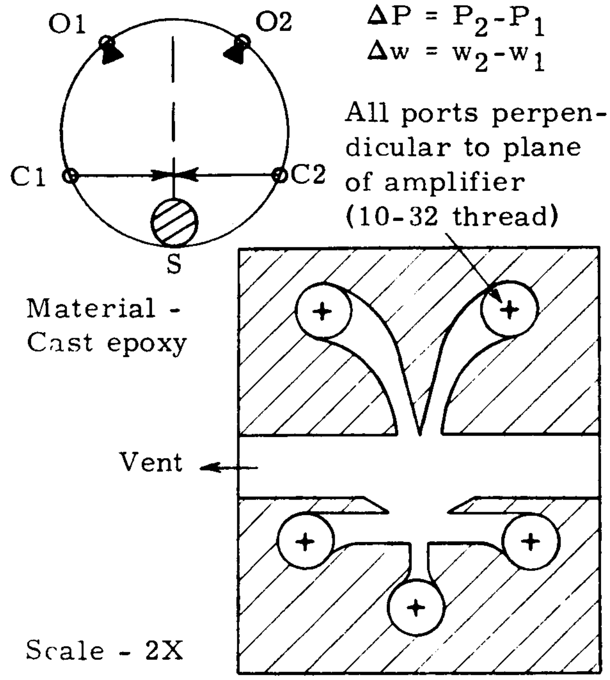
		Typ.	Max.	Min.
Power nozzle pressure drop (psig)				
	air	1.0	20	0.05
	H_2O	5	10	1
Power nozzle flow coefficient				
	air	0.90	---	---
	H_2O	0.85	---	---
Gain				
pressure				
	air	10	---	
	H_2O	12	---	
flow				
	air	8		
	H_2O	7		
power				
	air	---		
	H_2O	---		
Response (down 3 db)				
	air	0 to 1200 cps		
	H_2O	0 to 150 cps		
Signal/Noise Ratio	air	---		

(Input and output characteristics - see curves on reverse side.)

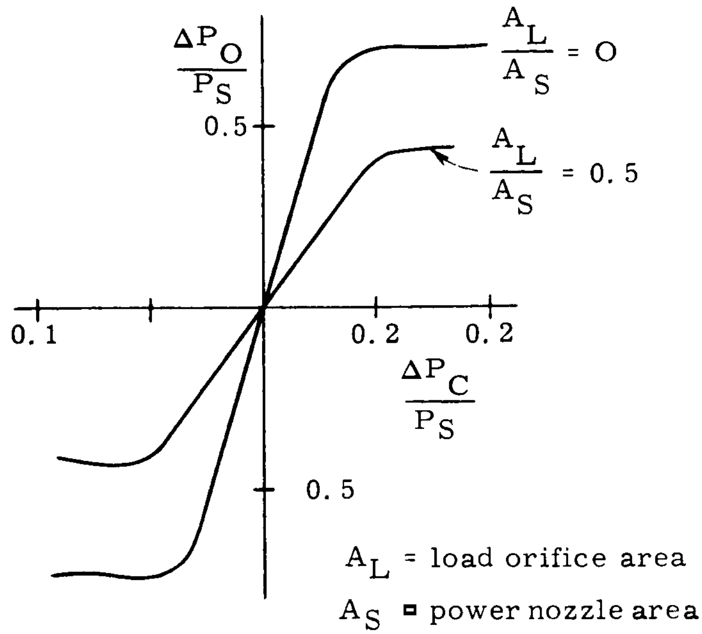
(6.0 Specification Sheet, Cont.)

SAMPLE (numerical values listed are hypothetical) BACK

OUTLINE

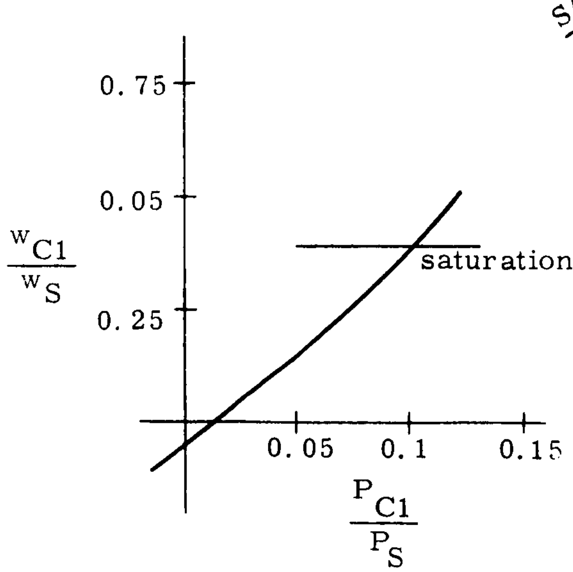


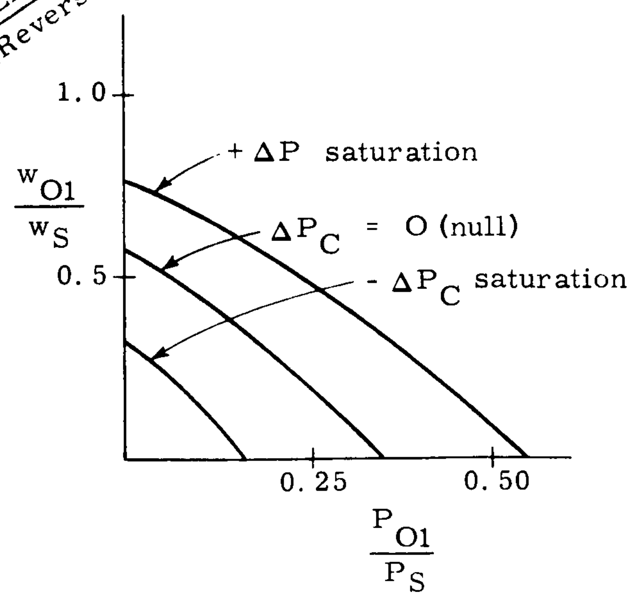
INPUT - OUTPUT CURVE



SAMPLE SPEC SHEET (Reverse Side)

CONTROL PORT CHARACTERISTICS





APPENDIX

The laboratories listed below contributed information useful in the preparation of this Manual. Where it was practical, the items in the Manual represent an "average" of the information contributed. The inclusion of any laboratory in the list below is not intended to suggest that the laboratory endorses the contents of the Manual nor that the contents represent their particular usage.

Contributing Laboratories

Raymond N. Auger and Company
Bowles Engineering Corporation
Case Institute of Technology
Corning Glass Works
Franklin Institute of Technology
General Electric Company
Giannini Controls Corporation
Harry Diamond Laboratories
International Business Machines, Endicott, N. Y.
International Business Machines, Zurich, Switzerland
Johnson Service Company
Marquardt Corporation
Massachusetts Institute of Technology
Moore Products Company
NASA, Lewis Research Center
Sperry Utah Company
Stanford Research Institute
Univac

NASA-Langley, 1964 CR-147